

U.S. Mines, Bureau of
Bulletin 45

DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

JOSEPH A. HOLMES, DIRECTOR

SAND AVAILABLE FOR FILLING MINE WORKINGS

IN THE

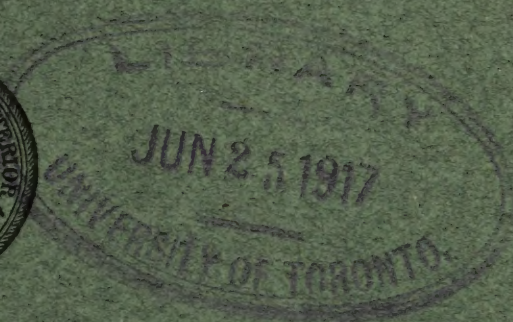
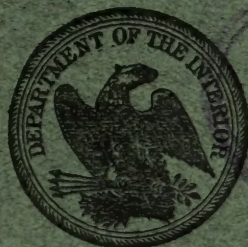
NORTHERN ANTHRACITE BASIN

OF

PENNSYLVANIA

BY

N. H. DARTON



WASHINGTON
GOVERNMENT PRINTING OFFICE
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NOTE.

The originating of the system of filling the workings of coal mines more or less completely with sand or other waste materials by flushing is to be credited to the anthracite operators in Pennsylvania; and though during the past few years the system has been developed more rapidly and more extensively in various European coal-mining centers, where conditions are more favorable than in this country, the European operators all give credit to the Pennsylvania coal men for setting so useful an example.

This small bulletin by Mr. Darton is not intended as a contribution to the engineering features of the methods of flushing. What Mr. Darton was requested to do, and endeavored to do, was to bring together in as short a space as practicable the results of his own observations and the observations of others concerning the general character and distribution of the unconsolidated materials available for filling the mine workings in the northern anthracite field of Pennsylvania. It is hoped that this volume may be of some service to the engineers who are endeavoring to work out in detail the problems that must be solved before it will be possible to determine definitely the extent to which it may be practicable, under the economic conditions existing at the present time, to use the flushing system in filling the mine workings of the anthracite region.

SAND AVAILABLE FOR FILLING MINE WORKINGS IN THE NORTHERN ANTHRACITE BASIN OF PENNSYLVANIA.

By N. H. DARTON.

INTRODUCTION.

In mining coal in the anthracite region of Pennsylvania the general custom has been to leave a large percentage of the coal in place as pillars to support the roof. Evidently any practice that involves partial waste of an important mineral resource is bound to be discarded. It is well recognized that one method of obviating probable waste is to fill the workings with cheap or worthless materials, a process extensively employed in the anthracite and some European mines. At present many of the collieries in the anthracite region of Pennsylvania are utilizing refuse from the old culm banks, which formerly were prominent features in the landscape, and are flushing the fine waste underground so that pillars may be reduced in size or removed. As a result the banks are now disappearing and soon will be gone. The fine culm from the breakers and rock from the mines will continue to be available, but the volume of these materials is insufficient to replace any considerable proportion of the coal removed. The next stage of progress suggested is the use of sand. Fortunately there are available large deposits of this material, much of which can be handled by dredges and pumps.

This report is issued by the Bureau of Mines in the interest of safer and more efficient mining methods. Its purpose is to describe the sand deposits in the northern anthracite coal field in Luzerne and Lackawanna Counties, Pa. Much of the information available is presented in the map, Plate I. Field studies, mostly preliminary, were made in the summer of 1911 to determine the distribution, amount, and character of the larger deposits. It was not thought desirable to make a detailed examination of the region because when the coal companies decide to utilize the sand their engineers will make precise surveys and drill test holes.

In preparing the map the various coal companies were consulted; they contributed a large number of facts, especially as to the deposits in the buried valley of the Susquehanna between Pittston and Nan-

ticoke, where nearly 1,000 test holes have been bored. The results of these borings were placed at the author's disposal, and have been utilized in drawing the boundaries given in the wide valley area and its extensions up Lackawanna River and Newport Creek. Wyoming Valley contains deposits of sand that are 100 feet thick over a wide area, 200 feet thick in places, and over 300 feet thick in the deep old channel south of Plymouth.

GEOLOGY OF SAND DEPOSITS.

In the northern anthracite coal field sand occurs in different situations and under different conditions, as follows: (1) Buried river channels; (2) old channels considerably higher than the level of the present river flats; (3) glacial till of various kinds, including the general glacial detritus, moraines, and kames; and (4) rear-ranged till.

BURIED RIVER CHANNELS.

In glacial time, and perhaps partly in preglacial time, some of the valleys of the region were excavated much deeper than they are at present. These deep channels were later filled with gravel, sand, and clay, so that the present streams flow much above the level of the old waterways. In places the depth of the sediments filling these old channels is over 300 feet, but generally the depth is from 100 to 150 feet. The valley of the North Branch of the Susquehanna is one of the most notable examples of such filling, for from Pittston to Nanticoke its wide bottomlands are underlain with a deposit of sand, gravel, and clay, which attains a thickness of 309 feet at one locality and is more than 100 feet thick under an area of nearly 20 square miles. The lower course of the Lackawanna River, much of the valley of Newport Creek, and many minor valleys are floored with a greater or less depth of sand and gravel, filling an earlier deep channel. Wilkes-Barre is built over an old channel cut by Mill Creek when it flowed into the Susquehanna at a point under the southern part of the present city.

OLD TERRACES.

Along the lower slopes of the mountains on either side of the Wyoming Valley and along parts of the valley of the Lackawanna there are remnants of terraces from 60 to 180 feet above the level of the river flats. These terraces are mostly built of sand and gravel in inclined beds deposited by streams, presumably near the close of the Glacial Epoch. Probably they were once much more extensive, for much material has been removed by postglacial erosion. Most of the deposits appear to be in deltas of streams which flowed laterally into the larger valleys when these valleys were occupied by a thin tongue of ice at the edge of the retreating glacier. Some of these terraces are



A. MORAINIC DRIFT LEFT BY GLACIER ON MOUNTAIN SLOPE BETWEEN BLISS AND ALDEN COLLIERIES SOUTH OF NANTICOKE, PA., CONSISTING OF SAND, GRAVEL, AND BOWLDERS.



B. SAND AND GRAVEL IN HIGH TERRACE OF OLD DELTA OF TOBY CREEK, LUZERNE, PA.



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in corners where there is an abrupt turn in the course of the main valley. One of the most notable examples of the latter class is at Pittston, where the terrace is 125 feet high and built entirely of sand and gravel for some distance. At Luzerne there is a high terrace probably representing a delta of Toby Creek at an earlier stage of the topographic development of the region. In these terraces the materials are assorted and bedded, and generally the beds are steeply inclined in one direction or another.

GLACIAL TILL.

The ice of the Glacial Epoch occupied the entire area of the northern anthracite field and left a sheet of till which was interrupted only by steep rocky slopes. In places, however, subsequent erosion has removed some of this till and in certain areas the material has been worked over and redeposited. The till consists of a heterogeneous mass of sand and gravel with local admixtures of clay and boulders. As a rule, the proportion of clay is small, sand forming more than 50 per cent of the deposit. The thickness of the till varies from a thin veneer to 150 feet. The average thickness is 15 to 20 feet. Some of the thickest masses lie along the lower slopes of the mountains on the northwest side of the basin. Deposits of this character occur northwest of Scranton and northwest of Old Forge and Duryea, from West Pittston to Luzerne, and at Plymouth. Isolated hills of till occur at some localities, notably at Plains, where there is a large mass; there is another extensive area north of Peckville. At various places there are conspicuous till hills with rock cores, and in some of these the rock protrudes on the summits or at intervals along the sides.

Morainal till occurs in a few localities. It consists of groups of hills and basins as shown in Plate II, A, and was built up at the edge of the glacier during a pause in the retreat of the ice front. The best examples are in the slope a half mile east of Alden (Pl. II, A) and in the locality just north of the Holden colliery.

REARRANGED TILL.

During its deposition, especially on the retreat of the glacier, much of the till was subject to the action of running water which washed and rearranged the materials to a greater or less extent. At some localities the sand was carried downstream and spread out in a layer and then covered with gravel deposited by a stronger current. The result was alternating layers of coarse and fine materials. Such deposits are numerous throughout the region, and much of the high terrace material mentioned above was so deposited. Possibly considerable of it was laid down when the deeper part of the valley was filled with ice.

BURIED VALLEY OF THE SUSQUEHANNA.

GENERAL STATEMENT.

From Pittston to Nanticoke the North Branch of Susquehanna River flows in a broad, flat-bottomed depression known as the Wyoming Valley. The width of the river flats slightly exceeds 2 miles near Wilkes-Barre, but decreases to a mile below Plymouth and to somewhat less near Nanticoke. The river banks vary in height from a low flood plain to bluffs rising 25 feet above the water. Low terrace steps, at various heights, extend up and down the valley, especially on its north side. Wilkes-Barre is built on one of these terraces which extends up a southwestern extension of Mill Creek Valley. Back from the river there are remnants of higher terraces, notably at Pittston (Pls. I and III) and west of Kingston and Luzerne (Pls. I and III).

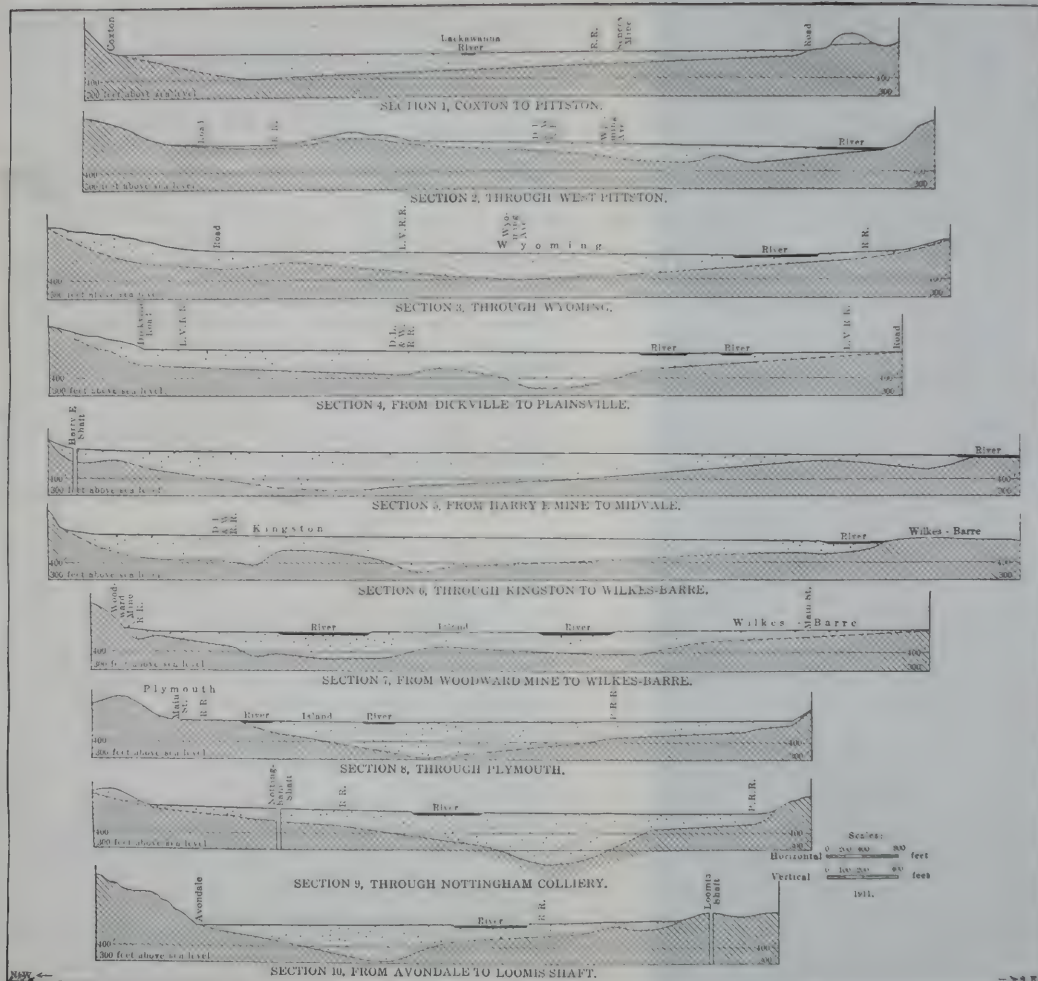
The flats and terraces mentioned above are underlain with a heavy body of river deposits that are more than 100 feet thick in the greater part of the area and in places exceed 300 feet in thickness. The map, Plate I, and the cross sections, Plate IV, show the thickness of this valley filling as determined by many hundreds of holes bored by coal-mining companies. The cross sections are constructed along lines shown on the map and are so spaced as to show the principal conditions along the old valley. This old valley was described by I. C. White,^a and further information was given by F. A. Hill.^b Some years later William Griffith^c prepared a contour map showing the principal features so far as they could be determined by the bore-hole records available at that time. Plate III is a similar map, with 50-foot contours platted from all the data available in 1911. Some of the details differ from those shown in the Griffith map, but the facts have been brought to light by many new holes sunk during the past decade.

For much of its course below Pittston the Susquehanna River flows along the southeast side of the flats and in places cuts into the rocks which rise into the hills to the south. These rocks also outcrop as ledges in the river at Pittston, and also in Wilkes-Barre from Midvale to North Street Bridge. They rise in bluffs along the southeast bank from Pittston to Port Griffith and from Port Bowkley to North Street, Wilkes-Barre. At South Street the river deflects abruptly to the northwest and crosses the wide low flat to the foot of rocky bluffs at the mouth of Toby Creek. These bluffs thence extend to Plymouth, where the sandstone ledges finally pass out under the river opposite and below Richard Island. Below this point the river deflects again to the left, and at Butzbach the bank presents high

^a 2d Geol. Survey Pa. Rept., vol. G 7, 1883, p. 26.

^b 2d Geol. Survey Pa. Ann. Rept. for 1885, pp. 637-646.

^c Wyo. Valley Hist. and Geol. Soc. Proc., vol. 6, 1901, pp. 27-36 and plate.



STRUCTURAL SECTIONS OF THE BURIED VALLEY OF THE SUSQUEHANNA.

ledges of rock. Below the mouth of Warrior Run the stream recrosses its valley to the rocky ledges at the Chauncey colliery, and a short distance below West Nanticoke passes into a deep gorge.

The deepest part of the buried valley is at Plymouth, where for 3 miles its bottom is more than 200 feet below the present river bed, at one place a depth of 309 feet being found. Channels more than 200 feet below the surface also occur at intervals from Kingston to Wyoming. From a point near Nanticoke to Exeter the bottom of the old valley lies more than 100 feet below the present river bed, the average width of the deep portions being more than 1 mile. At West Pittston there are several underground channels and ridges, the deepest depressions being 110 to 125 feet below the present river. These channels were excavated in rocks of the coal measures, which are sandstone, shale, and fire clay, and a very large tonnage of coal was also removed. The buried valley, however, has not a continuous down grade, but its deeper portions decrease in depth downstream; in other words, the deeper channels are elongated basins closed by rock at the ends. Probably the deepest channel at Nanticoke is not quite 100 feet deep, unless it is very narrow. As noted by White and Lesley,^a the river bed is in rock at Bloomsburg, and near Sunbury at altitudes higher than the bottoms of the deeper underground channels. In consideration of this fact Lesley^b has suggested that the depressions were excavated by streams flowing under the glacier.

COXTON TO WYOMING.

The buried valley of the Susquehanna presents great irregularity in configuration for the first few miles of its course. It begins at some unknown point in the gorge above Coxton, and as the river flows into the Wyoming Valley north of Pittston its width rapidly increases to about $1\frac{1}{2}$ miles. There are many irregular channels and basins in its bottom and the thickness of the sand and gravel varies from 10 to 172 feet. Some of the features are shown in the two upper sections of Plate IV. The main deep channel extends under Scovell Island, through the east end of West Pittston, and then curving around to the west coincides nearly with a line from Wyoming Avenue to Exeter. At one point on Scovell Island the sand is 172 feet thick. There is a shallow back channel passing near the Stevens and Troy collieries separated by a high rocky hill which projects above the general plain just northeast of the Exeter colliery. This hill is thinly covered with till and flanked with high terrace deposits which are dug to some extent in several sand pits. Under the built-up portion of West Pittston the river deposits show great variations in thickness. In general there is a regular increase from 50 feet at Clear Spring shaft

^a 2d Geol. Survey Pa. Rept., vol. G 7, 1883, pp. xv-xvi.

^b Loc. cit.

to 128 feet at the north end of the lower bridge. Possibly the center of the channel may be farther south under the river, but along the south shore at the end of the upper bridge the rock rises to the surface. The rock also appears along the south bank of the river from the lower part of Pittston nearly to the Hoyt colliery. In the southern and western parts of West Pittston and also in Exeter, many bore holes indicate the thickness of the valley filling in much of the area. On the north bank of the river for a long distance the depth to bed rock is 40 to 60 feet. In the lower part of Exeter there is a deep channel in which the thickness varies from 104 to 128 feet, but it is separated from adjoining channels by low rock ridges. At the Exeter shaft the rock rises rapidly to within 29 feet of the surface. West of this place there is gradual deepening to 110 feet at the Schooley shaft and to 132 feet at the Mount Lookout shaft. These shafts are along a deep channel south of which is an underground ridge of considerable height. South of this ridge there is another deep channel that appears to begin in the southern part of Exeter a short distance from the north bank of the river. These two channels join in the eastern part of Wyoming.

The materials underlying the valley between Coxton and Wyoming present frequent changes of character. Sand and gravel predominate, but portions of the sand are reported as quicksand and there are local clay deposits of limited extent. A bore hole on the west side of Scovell Island disclosed strata as follows: Clay, 7 feet; gravel, 39 feet; sand, 20 feet; quicksand, 34 feet; gray sand, 14 feet; quicksand, 8 feet, and gray sand, 30 feet, on slate. Another boring on the east side of the river opposite the island showed the following strata: sandy clay, 50 feet; hard pan, 26 feet; quicksand, 29 feet; gravel and sand, 17 feet; quicksand, 4 feet; hard gravel and boulders, 3 feet; and quicksand, 1 foot, on sandstone. A hole 30 rods southeast of Seneca breaker revealed deposits as follows: Gravel, 12 feet; sand, $7\frac{1}{2}$ feet, and clay, 6 feet, on rock. A hole three-fourths of a mile northeast of Wyoming station showed strata as follows:^a Gravel, 38 feet; blue clay, 12 feet; sand 59 feet, and sand and rock 7 feet, on sandstone.

A very large amount of sand is available for mine filling in the district between Coxton and Wyoming. The river is underlain with from 50 to 100 feet of sand deposits at most places and these could be dredged into deeply at several places without interfering with the adjoining banks. A part of the flats about Scovell Island might be deeply excavated to afford filling for workings in that direction. The mass of till and the valley filling in the western part of West Pittston contain a large supply of sand that is convenient to the collieries in the vicinity.

^a Pa. Geol. Surv. Northern Anthracite Coal Fields Atlas, col. sec. sheet VI.

WYOMING TO FORTY FORT.

The buried valley of the Susquehanna averages $1\frac{1}{2}$ miles wide from Wyoming to Forty Fort, and most of it lies on the north or right-hand side of the river. Fairly representative cross sections are given in sections 3 and 4, Plate IV, but there are many local variations, as shown in the map, Plate I. In general the depth of the deposit is from 100 to 150 feet, but there is a high underground ridge southeast of the Westmoreland colliery and a basin over 200 feet deep near the southeast margin of the Maltby workings. In connection with the Forty Fort, Maltby, Westmoreland, and Henry collieries numerous test holes show precisely the configuration of the rock floor in certain parts of these areas, and the Pennsylvania Coal Co. has a series of holes near the river from Plainsville to Hoyt colliery. (See Pl. III.)

Under the river the gravel and sand is mostly 60 to 100 feet thick, the thickness increasing to 100 feet along the north bank. Opposite Plainsville for some distance and about midway between the river and Wyoming Avenue is a deep buried channel containing from 200 to 227 feet of sand and gravel. This channel appears to extend west toward the mouth of Abraham Creek, but in that district there are no borings. Next north is an underground ridge that lies a short distance south of Wyoming Avenue and extends parallel to that avenue nearly to Forty Fort. In places on this ridge the thickness of sand and gravel is only 80 feet. Extending south and east of the Westmoreland colliery there is also a long, wide, underground ridge of rock that rises to within 48 feet of the surface along the railroads a half mile southeast by east of the colliery. Southwest of this ridge, and extending across the Maltby and the Forty Fort properties, is a wide channel in which the rock lies 100 to 150 feet below the surface. At the "cave" a quarter mile southeast of the Maltby breaker the sand and gravel is 146 feet thick. Northwest of the Back Road, from Troy to the Forty Fort collieries there is a bank of glacial till extending a short distance up the mountain slope. Part of the till presents a flat-topped terrace, other parts being in hills or slopes. This till varies in thickness, but in places northeast of the Westmoreland colliery it is more than 100 feet thick. It is predominantly sandy but contains large boulders in places. Along the slope there is available many million yards that might be utilized for mine filling. At most places also considerable water for sluicing and flushing could be obtained.

The materials underlying the flats from Wyoming to Forty Fort present considerable variation, but sand and gravel predominate. Some of the sand is "quicksand," and there are local deposits of clay. A drill-hole record of the second Geological Survey of Pennsylvania

covers a boring made a half mile east by south of the Maltby breaker, and shows the following:

Record of drill hole one-half mile east by south of Maltby breaker.

	Feet.
Sand.....	0- 6
Gravel.....	6- 10
Sand.....	10- 12
Gravel.....	12- 31
Sand.....	31- 51
Quicksand.....	51- 66
Clay.....	66-112
Quicksand.....	112-130
Quicksand and clay, on sandstone.....	130-144½

A quarter mile farther east on Wyoming Avenue a test hole showed 70 feet of sand and gravel, 20 feet of clay, and 73½ feet of "quicksand," a total of 163½ feet. About a half mile east of the Wyoming Avenue bridge across Abraham Creek a bore hole showed 50 feet of sand and gravel, 20 feet of clay, and 111 feet of "quicksand," on hard rock. Near the river northwest of the lower end of Monaconock Island one hole penetrated clay 13 feet, gravel 35 feet, brown sand 17 feet, "quicksand" 23 feet, and gravel 3 feet, to rock; another hole 25 rods south penetrated clay 8 feet, gravel 31 feet, sand 10 feet, and "quicksand" 48 feet, to shale. An old bore hole a few rods east of the Forty Fort breaker penetrated 4 feet gravel, 5 feet sand and clay, 10 feet gravel, 9 feet 10 inches clay and gravel, 9 feet 3½ inches "quicksand," 12 feet 10½ inches sand and clay, 14 feet clay, 4 feet 9½ inches coarse sand containing coal fragments, 9 feet 8½ inches "quicksand," and 1 foot 10 inches coarse sand lying on a coal bed.

FORTY FORT TO LUZERNE.

The village of Forty Fort lies on the south slope of the buried valley, the central channel of which extends just north of the Delaware, Lackawanna & Western Railroad. In this vicinity the bottom of the valley is slightly more than 200 feet below the surface. Some of the features are shown in cross section in Plate IV. Approaching Luzerne the bedrock rises toward the surface and finally outcrops in the creek bottom just above the Louise colliery. Luzerne lies largely above a deep embayment of the buried valley which contains in the greater part of its area an extensive deposit of sand and gravel 50 to 100 feet thick. Part of this thickness is due to the rise of the land in terraces considerably higher than the lowlands of the river flat. One of these terraces is finely exhibited on the end of the rocky ridge just west of the Black Diamond colliery, and another part of it extends along the foot of the mountain slope between the Louise and the Harry Ecollieries. The configuration of the buried valley about Forty Fort has

been determined by numerous borings. A large part of the area is underlain with a mantle of sand and gravel 100 to 150 feet thick, but there are several deeper basins and rock knolls underground. The deep channel north of the Delaware, Lackawanna & Western Railroad appears to extend nearly to Bennett Street, as a bore hole on the Black Diamond colliery a square and a half east of that street was sunk 224 feet before reaching bedrock. The deepest hole reported is one near the point at which the switch to the Harry E colliery leaves the main line. This hole is 230 feet deep. There is a rapid rise in the bedrock a short distance south of that colliery, at one point the bedrock being within 37 feet of the surface. At the Harry E shaft the thickness of gravel and sand was found to be 85 feet, and at the Forty Fort colliery the thickness increases abruptly from 2 feet near the shaft to 81 feet a few yards east.

The materials underlying the Forty Fort area present the usual variations found in other localities, but sand, gravel, and "quick-sand" of varying thickness predominate. There are local beds of clay near the river. Near the road forks at Forty Fort, one bore hole penetrated clay 2 feet, coarse gravel 29 feet, sand 8 feet, and quicksand 36 feet, on shale. A short distance farther southeast on the river bank the record was: Gravel 30 feet, clay 50 feet, and quicksand 20 feet, on soft rock. In the southern part of the village a hole penetrates gravel 58 feet, sand 6 feet, and quicksand 26 feet, on shale. Near the west end of the Port Bowkley bridge, a few rods southeast of the hole last mentioned, is a hole which penetrates gravel 30 feet, clay 30 feet, and sand 17 feet, on dark sandstone. Near the point where the branch of the Lehigh Valley Railroad crosses Wyoming Avenue, a hole 115 feet deep penetrated gravel 38 feet, sand 18 feet, and quicksand 59 feet, on shale. The Tripp No. 1 bore hole,^a presumably located just north of the Delaware, Lackawanna & Western Railroad tracks and southeast of the Harry E colliery, was 215 feet deep, showing nothing but valley filling. The record given by the State Geological Survey is as follows: Sand and gravel 25 feet, quicksand 70 feet, soft clay 100 feet, gravel with water 10 feet, and boulders and broken rock 10 feet. The Tripp No. 11 bore hole, a few hundred yards farther northwest, penetrated gravel and quicksand 30 feet, quicksand 60 feet, soft blue clay 60 feet, hard bed 2 feet, hard blue clay 20 feet, soft blue clay 15 feet, and gravel 4½ feet, on soft sandstone, 190 feet in all.

I. C. White^b mentions a hole, on the Shoemaker land near Forty Fort and about 40 rods south of the railroad, in which bedrock was reached at a depth of 212 feet, or 340 feet above sea level. The material penetrated was all fine mud and quicksand.

^a 2d Geol. Survey Pa. Rept., Atlas northern anthracite coal field, col. sec., sheet No. 3.

^b 2d Geol. Survey Pa. Rept., vol. G 7, 1883, p. 25.

Along the river the thickness of material gradually increases to 100 feet in the bend at Forty Fort, and if some of the material were dredged out, it would be replenished in some measure by the freshet deposition of the stream. Some of the low terraces in the river flat might possibly be cut down without great damage to the land value. A large quantity of sand might be sluiced out of the higher terrace slopes near Luzerne and extending along the foot of the mountain slopes past the Forty Fort, the Harry E, and the Louise collieries. The region has been extensively mined, but by refilling the old workings with sand flushing a great tonnage of coal could be recovered.

KINGSTON-DORRANCETON AREA.

Kingston is underlain with a wide deposit of sand, gravel, and clay of the old channel of the Susquehanna. This deposit is slightly more than 200 feet thick just north and east of Kingston Corners and is 125 to 170 feet thick along the Delaware, Lackawanna & Western Railroad east of Market Street. To the west and north of the last-mentioned point it rapidly thins to less than 65 feet, and it is less than 100 feet thick in a rather large area extending north and east of the corner of Chestnut and Pringle Streets. The rock surface also rises near the corner of James Street and Wyoming Avenue, and near the corner of Rutter and James streets the sand-and-gravel cover is only 80 feet thick. South of this place to a point near the river bank there are few bore holes. At the river bank the rock gradually rises to within 50 to 75 feet of the surface. The only boring in the upper part of Dorranceton is near the corner of Dorrance and Railroad Streets, where there is 163 feet of gravel, sand, and clay. This boring probably penetrates to a point near the bottom of the deep channel which extends southwest near Luzerne depot. Farther north there is a gradual rise of bedrock, which comes to within 52 feet of the surface near East Boston shaft. A typical section at a hole a square east of Kingston depot shows soil and loam 11 feet, gravel and sand 27 feet, blue clay 90 feet, fine sand 21 feet, and gravel and sand 9 feet, on sandstone. Another hole a few rods south of Kingston Corners showed soil and clay 14 feet, gravel and sand 44 feet, blue clay 82 feet, fine sand 12 feet, and gravel and sand 11 feet. This succession appears to be general under Kingston, notably in having the widespread sheet of clay which is over 100 feet thick at the corners of Chestnut and Maple and Chestnut and Hoyt Streets. The relations of this great clay sheet along a northwest to southeast section through Kingston are shown in figure 1. The strata in the eastern part of Dorranceton are shown in figure 2, which is based on a series of test holes bored at short intervals across the Pettebone colliery.

In Dorranceton and Kingston there are extensive built-up areas and tracts held for building lots. On the lower part of the river flats there are farming and overflow lands from which perhaps sand could be obtained for mine filling. There is also a large amount of sand in the river bed above Wilkes-Barre. The conditions along the river are shown in Plate V, A.

By dredging out the river channel the danger of freshet overflow might be diminished, and high water which carries a heavy load of sediment would deposit extensively in any holes made by dredging.

WOODWARD TO WILKES-BARRE.

The Woodward colliery lies on the slope of a hill which descends rapidly into the river flat. To the westward this hill consists of rock; to the eastward in Edwardsville the rocky core is thickly flanked with till. The relations under the river flat to the southeast are shown in section 7 of Plate IV, based on frequent borings made by the coal company. These borings show a gradual descent of the rock surface, the deposit of gravel and sand finally reaching a thickness of 158 feet. Farther south under the island in the river the rock rises into a ridge of moderate prominence and then descends again to 140 feet below the surface, as shown in a bore hole on the river drive of Wilkes-Barre. The western extensions of the ridge and of the depression have not been traced. Some bore holes near the Kingston line, at a point about a half mile east of the Woodward breaker (east

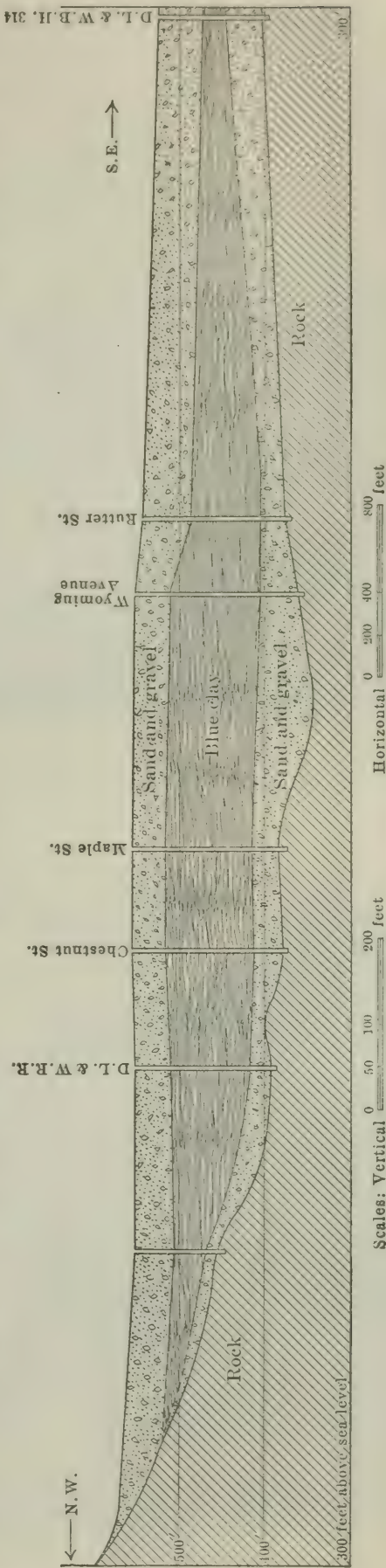


FIGURE 1.—Relation of valley deposits under Kingston, Pa.

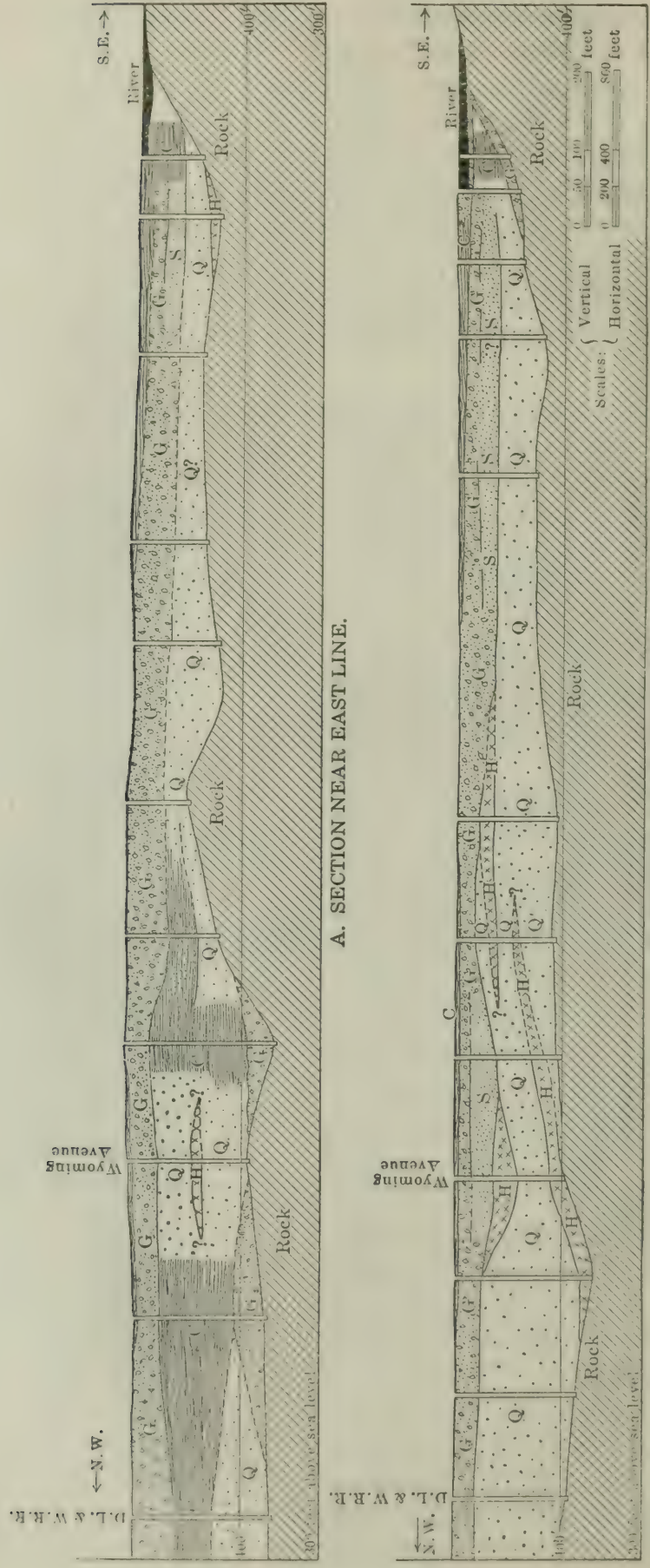


FIGURE 2.—Sections showing character of valley deposits in the Pettibone colliery area; S, sand; Q, quicksand; C, clay; G, gravel and sand; H, hardpan.



A. LOW-WATER STAGE OF NORTH BRANCH OF SUSQUEHANNA RIVER AT WILKES-BARRE, PA., SHOWING SAND AND GRAVEL RECENTLY DEPOSITED BY SPRING FRESHETS.



B. SAND PIT IN HIGH TERRACE AT KINGSTON NO. 1 COLLIERY, EDWARDSVILLE, PA. MUCH OF THE SAND IN THIS DEPOSIT IS FREE FROM BOWLERS.

of the area shown in sec. 7, Pl. IV) disclosed a thickness of 202 feet of sand and gravel, indicating local deepening of the northern channel, doubtless extending continuously from the channel that is so clearly defined in the central part of Kingston. The thickness of the sand and gravel in Wilkes-Barre at the south end of section 7 has not been ascertained; so far as known, no borings have been made south of the 140-foot bore hole above referred to.

There is a large amount of sand under the river bed and the low flats between Wilkes-Barre and the Woodward colliery, especially on the right side of the river, where there are low islands and overflow areas. A view of part of this region is given in Plate VI.

PLYMOUTH TO NANTICOKE.

The buried valley of the Susquehanna reaches its greatest known depth at Plymouth where the two deepest bore holes of the Lehigh and Wilkes-Barre Coal Co. have been drilled. One of these holes passed through 302 feet of sand and gravel, and the other hole showed 309 feet of sand and gravel before reaching bedrock. These holes are shown on section 8 in Plate IV. Borings a short distance south of these holes show, respectively, 293, 241, and 158 feet of deposits, but the bedrock floor rises more gradually to the north and up and down the line of the old channel. This channel trends east by northeast closely parallel to the average course of the present river. Between the bridge above Avondale and the upper end of Richard Island the Lehigh & Wilkes-Barre Coal Co. has sunk about 125 special holes to ascertain the thickness of the sand and gravel. These holes are so located as to show the outline of the configuration of the bedrock floor (as shown in Pl. III), except in an area of considerable extent in the flat southeast of Richard Island. The data, however, show that the main buried channel diminishes in depth in that area, probably to about 150 feet at the railroad bridge. The channel bifurcates in that vicinity; the main branch extends northeast and southwest down the main old valley, and the other branch, extending from Wilkes-Barre, is probably the old course of Mill Creek.

Between the Dodson and the Lance collieries in the upper part of Plymouth a ridge of rock projects some distance south under the river flat. The sandstone outcrops in the river bank at the bridge just south of Lance, and it is not far below the surface under the river and flats for some distance south. On the south side of the river opposite Dodson the rock is covered by a thin deposit of coal drift brought down the river and dropped in the slack water below the island. This material is now being dredged out and pumped over to the Dodson colliery, where the coal is separated from the gravel and sand. The deposit contains 60 to 75 per cent of coal.

The extension of the old river channel southwest from the line shown in section 8 of Plate IV is well defined by borings, for there are many holes on the Avondale area and others farther down the valley. That the channel gradually becomes shallower downstream is clearly shown. At the railroad bridge at Nanticoke the thickness of deposits may be less than 100 feet, as a group of borings on the south bank on either side of the bridge shows an average depth of 70 feet, the greatest depth being 75 feet, whereas on the opposite shore there are rock outcrops. However, it is possible that there is a deep but very narrow channel under the middle of the river at this place.

OTHER DEPOSITS OF SAND AND TILL.

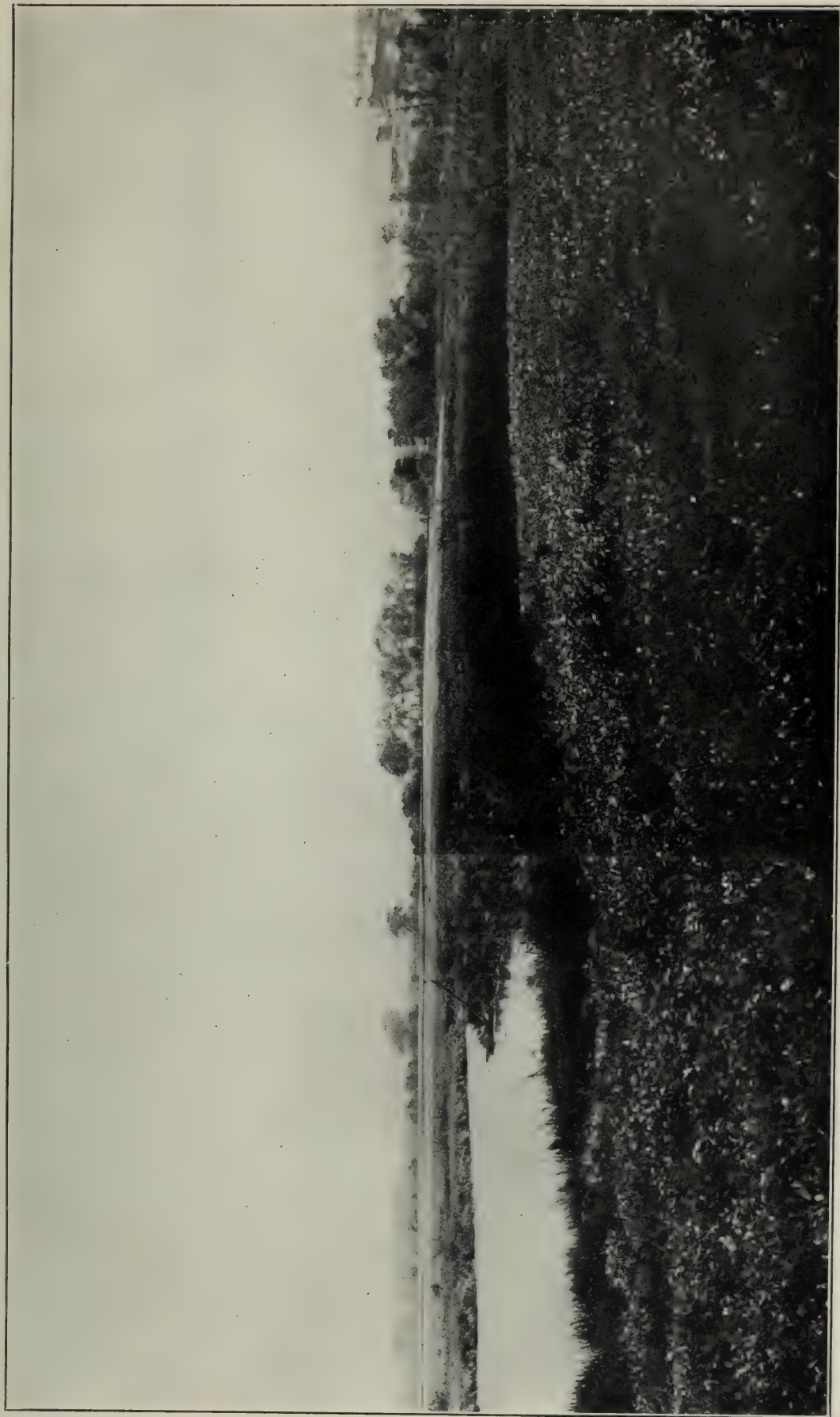
VALLEY OF NEWPORT CREEK.

Newport Creek flows down a wide valley which in general is a southwestward continuation of the depression occupied by the north branch of the Susquehanna River. Its surface rises rapidly to the southwest and has little of the broad low terracing so characteristic of the river flats. However, it contains a thick body of similar sand and gravel occupying an ancient channel which in places was cut more than 100 feet deeper than the present surface of the river at Nanticoke, but not so deep as the old river channel. The deposit is in places over 250 feet thick, extending nearly 150 feet below the bed of the creek and constituting adjacent terraces and hilltops 100 feet higher. Its greatest width is about 2,400 feet at a point about a half mile above Nanticoke. Nearer Nanticoke the width is only 1,600 feet, and near colliery No. 2 of the Susquehanna Coal Co. it is only 1,150 feet wide, its bottom lying only 82 feet below the creek. Near the Stearns colliery above Nanticoke there is also a diminution in the thickness of deposits and in the depth of the old valley, but the deposits are easily traceable as far as Glen Lyon and beyond. Some features of this valley were described by Asburner,^a and its configuration was represented on the contour map by Griffith.^b Later borings made by the Susquehanna Coal Co. have added some very important data, especially as to the area north of colliery No. 2, where seemingly there is a rapid rise in the floor of the old valley, as shown in the top section of figure 3. This figure is based on recent investigations along several lines of cross sections so located as to show the salient features on the lands of the Susquehanna Coal Co. In the figure 11½ feet have been added to the Susquehanna Coal Co.'s elevations to bring them to sea-level datum.

In the valley of Newport Creek there is a very great volume of material available for filling the extensive coal workings near the

^a 2d Geol. Survey Pa. Rept. for 1885, pp. 627-636.

^b Wyo. Valley Hist. and Geol. Soc. Proc., vol. 6, 1901, pp. 27-36.



THE BROAD ALLUVIAL FLAT ALONG THE SOUTH SIDE OF SUSQUEHANNA RIVER AT WILKES-BARRE, PA. THE FARM LAND IS UNDERLAIN WITH 100 TO 250 FEET OF SAND.

creek, but this material can hardly be carried very far up the south pitch workings on the adjoining mountain slopes or over the ridges into the workings southward. There are only a few buildings on the land, it being mainly in farms or pastures. The material is largely sand with scattered gravel deposits and boulders. Some portions are so fine grained as to be classed as quicksand. Newport Creek is a stream of moderate volume, but it would afford water for all necessary flushing. The valley widens considerably at Glen Lyon, where it contains a body of gravel and sand of variable thickness. Near the Catholic Church the depth to bedrock is 109 feet.

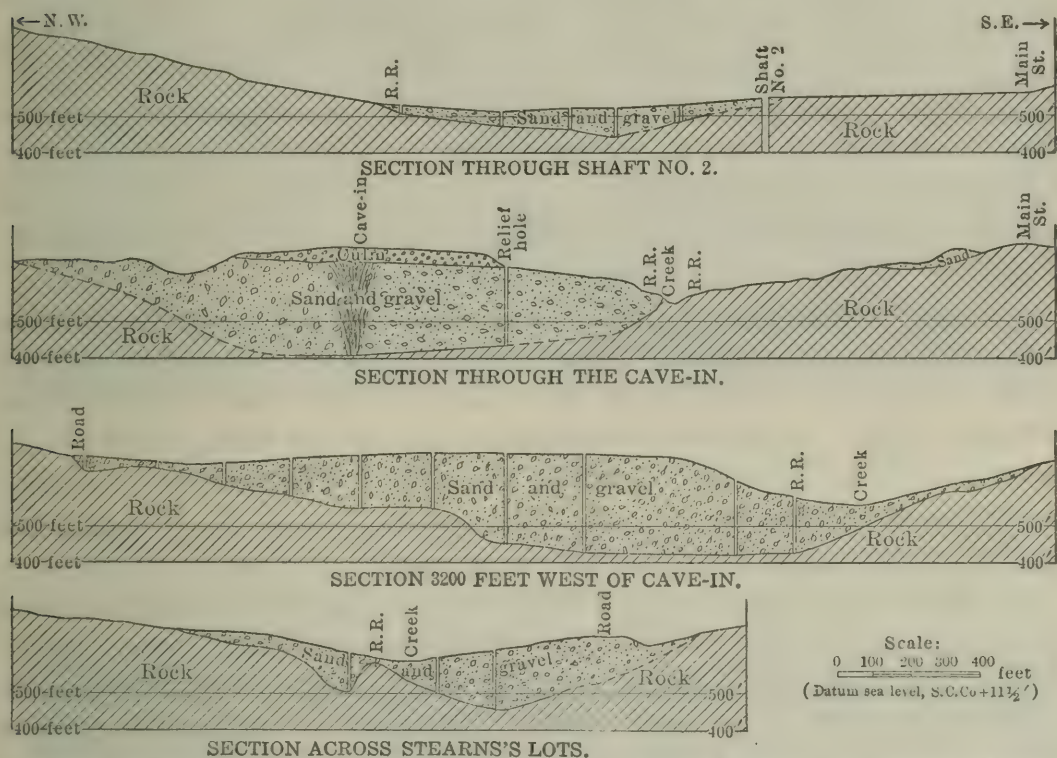


FIGURE 3.—Sections across the valley of Newport Creek at and near Nanticoke, Pa., showing relations of gravel and sand deposits.

OLD VALLEY OF MILL CREEK.

Mill Creek rises in many branches on the mountain slopes on the south side of the coal basin and empties into the Susquehanna River at the northeast corner of the city of Wilkes-Barre. At Hudson it flows out of a rocky gorge into a wide, flat-bottomed valley which extends through Miners Mills, Parsons, and Wilkes-Barre. The latter city is built largely on a terrace formed at the coalescence of the valley with that of the Susquehanna River. Since this terrace was formed, the river has cut to a somewhat lower level, as is shown by the high bank occupied by the admirable river park. Mill Creek now leaves its old wide valley at the north margin of the city and flows to the river in a short rocky gorge, a feature of relatively recent geologic origin.

The broad, flat valley of the creek from Hudson to and through Wilkes-Barre is underlain with gravel and sand partly glacial and partly deposited by the creek. Some of the borings of the Baltimore collieries of the Delaware & Hudson Co. show from 40 to 87 feet of sand and gravel in this valley. At the Pine Ridge shaft 44 feet is reported, at Hollenbeck shaft 30 feet, and at Baltimore tunnel 51 feet. Seemingly the thickest body occupies a channel extending southwest from the mouth of Laurel Run under the hill north of the Baltimore Tunnel mine. In a hole a few rods east of the crossing of the Nanticoke Branch of the Central Railroad of New Jersey and the Hazelton Electric Railway line the sand is 90 feet thick. The bottom of this buried valley rises somewhat near the Hollenbeck shaft where the sand is only 30 feet thick, but it is much deeper under the greater part of the level portion of Wilkes-Barre. Few deep excavations have been made in the old city area, but probably the sand and gravel is moderately thick throughout. The only definite record is the hole for the elevator plunger at the Second National Bank, where the depth to "bedrock" is reported to be 62 feet.

The sand and gravel of Mill Creek lie mostly below the level of the bottom lands of the valley, which are extensively occupied by railroads and houses. Bordering the valley, however, are several higher terraces, which might yield considerable sand for filling part of the extensive mine excavations under the area. The terraces are most conspicuous at Hudson, Miners Mills, the Baltimore No. 2 shaft, and on the extension of East Market Street south of Empire Street.

At Hudson the material is a thick mass of glacial till lying against the south end of the rocky ridge extending southwest from Inker-mann. There are no buildings on part of this till, especially a sloping area extending up the north side of gorge of Mill Creek for a half mile. This part is cut into deeply by the railroad grade at a point one-third mile northeast of Hudson station, revealing a heterogeneous mixture of sand, gravel, and boulders with a somewhat blue, sandy clay matrix, a typical glacial till.

There is a large mass of till and terrace deposit in the slope and ridge east and northeast of the village of Miners Mills. Its upper part consists of a delta deposit laid down by Mill Creek at an earlier stage of valley development and this deposit contains a large proportion of coarse sand. The deposit extends nearly a mile north over a low divide into the valley of the south fork of Mill Creek, but this higher part may not be very thick. The sand has been dug to some extent in pits behind Miners Mills and could be worked extensively for mine filling. The south end of this deposit extends into the east end of Parson, but the deposit is finally cut off by the valley of Laurel Run, which reveals rock down to the main road. The high



A. CURRENT-BEDDED SAND AT PITS NEAR EMPIRE AND MARKET STREETS, SOUTHERN PART OF WILKES-BARRE, PA. A LARGE THICK DEPOSIT OF NEARLY PURE SHARP SAND.



B. SAND IN TERRACE IN SOUTHERN PART OF WILKES-BARRE, PA. EXCEPT IN THIN CAP AT TOP OF BANK, FEW BOWLERS ARE PRESENT.

hill of till lying north of the Baltimore Tunnel mine is occupied by houses, so that little of its material is available for mine filling unless as a result of regrading the streets. The sand-and-gravel area lying south of Empire Street, east of Northampton Street, consists of slopes and terraces in which the deposit is more than 50 feet thick in places. In Plates VII, *A*, and VII, *B*, are shown views of the sand at two localities in this area where it is extensively dug for building purposes and for making concrete.

These sand pits are in a remnant of terrace rising from 25 to 30 feet above the adjoining surface, and as this terrace occupies several acres a large tonnage could be removed in bringing the land to uniform grade. It is estimated that the amount remaining is about 300,000 tons. A large additional tonnage could be obtained on the slopes south on the opposite side of the railroads.

OLD CHANNEL WEST OF EDWARDSVILLE.

Behind the high, rocky ridge extending from Edwardsville to the eastern part of Plymouth there is a wide depression containing a thick deposit of sand and gravel. These materials were deposited by a side channel of the river long ago and finally became a level-floored valley 160 feet higher than the present river. Wide areas of this elevated valley filling remain between the Kingston No. 1 colliery, and the Plymouth No. 3 colliery, and they are striking features of the landscape. The gravel-and-sand deposit lies on an irregular floor, but under an area of considerable extent in the plateau northwest and southwest of the Plymouth No. 3 mine it is over 105 feet thick. The material of this deposit is well exhibited in the large sand pits near the Kingston No. 2 breaker, as shown in Plate V, *B*. Sand predominates, but there is a considerable quantity of small gravel and scattered boulders. Part of the area is built on or is held for building lots, but a great tonnage of sand could be sluiced out and used for filling the Plymouth, Kingston, and Boston collieries.

TILL NEAR PLYMOUTH.

Along the lower slope of the mountain behind Plymouth and for some distance southwest there are thick deposits of glacial till and terrace material. The largest mass is north of Gaylord colliery, where the width is great and the thickness more than 100 feet, so that a large quantity of material is available. It consists largely of sand and gravel, with some boulders and probably a little clay. A smaller mass of similar material extends up the slope north and northwest of Nottingham colliery.

TILL FROM WILKES-BARRE TO HANOVER.

The southern portion of Wilkes-Barre is built on hills with rock cores more or less heavily mantled by till, but there are also areas of considerable size in which the rocks outcrop. Much of this district is built up with houses, but moderate supplies of sand may be obtained at many places. The till mantle is especially thick, widespread, and clear of buildings in the slopes and terraces east and southwest of the Franklin colliery. One high hill a half mile southwest of the Franklin shaft appears to consist entirely of till, although possibly there may be a rock core at its center. From a point a short distance east of the Empire colliery a deeply buried valley extends west for nearly a mile to a point beyond the Stanton colliery. Some borings in this area penetrated from 58 to 90 feet of sand and gravel. Possibly some of the material in this valley could be used for mine filling, but as it lies mostly below the general grade, the quantity available is not large. The same condition exists in the deep valley west of Ashley.

Most of the slopes adjoining Buttonwood Creek from the Maxwell colliery northward are more or less heavily flanked with till, some of which could be used for mine filling. The deposit is especially thick in the ridges west and southwest of the South Wilkes-Barre colliery, the proportion of sand in many places there amounting to 60 and 65 per cent. There are numerous high hills covered with till in the region adjoining Warrior Run, north of Sugar Notch and northeast and northwest of Askam. The thickness and relations of these deposits have not been revealed, for the area has not been mined, but judging by the configuration of the hills and the distribution of the rock outcrops at their base or along their slopes, some of them contain a large quantity of sand. Thick deposits lie along the north slope of the Hanover hogback ridge from the east fork of Warrior Run nearly to Nanticoke.

On the mountain slopes and the wide valley about the village of Warrior Run there is a large irregular till deposit that in places may reach a thickness of 60 to 70 feet. The largest mass constitutes the high rounded hill a half mile west of the village of Warrior Run.

Hanover is built on a terrace of gravel, sand, and boulders, the terrace extending for some distance west over the Bliss workings.

TILL AND TERRACES FROM NANTICOKE TO THE ALDEN AND BLISS COLLIERIES.

The upper part of Nanticoke appears to be built on a series of ill-defined terraces cut in the rocks and partly composed of glacial till. They rise to altitudes of 670 to 710 feet. The quantity of till in the built-up part of the city appears to be inconsiderable, but in the thinly settled district eastward there is a large mass of the deposit

which would afford a large quantity of sand for mine filling. This deposit extends back to the middle road and into the vicinity of the Auchincloss colliery. It appears again in large mass as a strongly marked terrace lying along the lower slope of the mountain at the Bliss colliery, extending thence continuously to the Alden colliery. The nearly level surface of this high terrace is a notable feature, but in places it is broken by slopes, exhibiting a succession of pits and knolls of typical moraine topography. This feature is shown in Plate II, A.

The thickness of the deposit varies from 40 to 80 feet, the latter figure obtained by a boring a few rods south of the Bliss shaft. Most of the material in this area is rearranged till, exhibiting inclined stratification and complete reassortment of materials. The view in Plate VIII, A, shows its character at a sand pit in the Alden settlement a half mile east of the Alden shaft. There is in this deposit a large quantity of sand that might be used for filling neighboring mine workings.

In the valley south of Alden there is a thick deposit of sand and gravel, and this same body also extends up the slopes west, constituting a well-defined terrace at an altitude of 680 feet, or the same level as the terrace on which much of Nanticoke is built, as mentioned in a foregoing paragraph. The gravel, sand, and bowlders of this terrace are well exposed in road cuts on the slopes. This deposit might afford an excellent supply of sand for filling mine workings in the vicinity.

TILL AT PLAINS.

The large hill at Plains which rises to an altitude of 810 feet consists largely of till seemingly wrapped about an irregular mound of rock. The total area of thick till is about 400 acres, and doubtless the thickness in places is more than 60 feet. The "Laurel Line" electric railroad has a deep cut through this till a few rods north of the Plains depot, and although the cut is walled for the larger part, the character of the deposit is visible in places. It is typical glacial till, a heterogeneous admixture of gravel, sand, and bowlders, with some clay in some portions. The proportion of sand is large, probably more than 50 per cent, and the clay constituent would not seriously interfere with the utilization of the deposit. Portions of the area are covered with buildings or are held as building lots, but there are places where a large volume of sand could be obtained for mine filling. However, the area is high above the river and much power would have to be expended in pumping water sufficiently high to sluice the sand into the mines.

HIGH TERRACE AND TILL AT PITSTON.

In the central and southeastern parts of Pittston there remains a considerable area of high terrace deposited at the time when the channel of the Susquehanna River was about 130 feet higher than at present. Much of the terrace consists of sand and gravel, but locally it is cut in the rocks. In places the sand-and-gravel deposits are more than 125 feet thick, extending down nearly to the level of the river, but they lie on a rocky irregular floor which rises rapidly north and east. The western margin is a steep slope or bluff of sand and gravel. The thickest body of the deposit is in the terraces on either side of the hollow followed by the "Laurel Line" in entering Pittston from the east. On the north side of this hollow the thickness was found to be 121 feet at one point and must be equally thick on the opposite side and for some distance south. An extensive pit near the "Laurel Line" and Erie depots shows the nature of the terrace deposit. (Pl. VIII, B.) It is sand, with gravel streaks, in beds inclined to the northeast. The percentage of sand is large, and most of it is clean and angular. In this neighborhood most of the surface is covered with buildings, so that only a limited amount of sand is available. Farther south, however, in the outskirts of the city and extending nearly to Yatesville, there are extensive vacant lots where a large quantity of sand could be obtained for filling the extensive mine workings in the vicinity.

Besides the terrace deposits at Pittston, there is on the surrounding slopes and ridges considerable till that could be utilized. One of the largest masses covers the high hill southwest of the No. 8 colliery, but it may have a high rock core and not be very thick. In the valley extending through the Butler and the Heidelberg No. 2 collieries to and beyond Dupont there is some gravel and sand, but the deposit thins to the westward and is not thick enough to afford much sand west of the Butler colliery.

TILL OF THE AVOCA REGION.

In the wide, irregular valley and low ridges north and west of Avoca there is an extensive mantle of glacial deposits of various kinds. Part of it is ordinary till, but most of the material is rearranged glacial sand and gravel laid down in wide ridges or terraces. Its thickness is variable, and low ridges of rock rise through it in places. There are few bore holes in the area to give a definite idea of the thickness of the deposit, but in many places it is fully 50 feet thick. Along the two railroads a half mile east of the Langcliff colliery there are large pits and cuts in which the sand has been excavated for various purposes. Much of the area is not occupied by buildings, and a large quantity of sand might be taken for filling the extensive workings of



A. SAND AND BOWLLER DEPOSIT IN HIGH TERRACE AT ALDEN, PA., WORKED FOR BUILDING SAND.



B. SAND PIT IN THE HIGH TERRACE BEHIND PITSTON, PA. CROSS-BEDDED SAND CONTAINING ONLY A SMALL QUANTITY OF PEBBLES AND BOWLLERS.

the many collieries that have mined under the district. There is in Mill Creek, which traverses the district, a small flow of water that might be used for sluicing and flushing.

LACKAWANNA VALLEY FROM PITTSTON TO LACKAWANNA.

The buried valley of the Lackawanna River extends from the upper part of Duryea to the river's mouth where it is confluent with the old valley of the Susquehanna River. A typical section of the buried valley at Duryea is shown in figure 4. The deepest part of this buried valley is under Scovell Island, nearly 3 miles from the point where rocky reefs cross the Lackawanna River at the Luzerne County line. The thickness of deposit at Scovell Island is 172 feet, indicating a fall in the old channel of about 50 feet to the mile, or as much as the total fall of the Lackawanna River from the upper part of Duryea. The old valley is more than a half mile wide, and there are few buildings in it. Sand and gravel, in variable succession overlying an irregular floor of bedrock, constitute the surficial deposits. Many test holes in connection with mining have been bored by the Lehigh Valley, the Lackawanna, and the Pennsylvania coal companies. At the Halstead colliery most of the bore holes in the river flat show from 40 to 90 feet of gravel and sand, but there are places in which the thickness diminishes to 15 feet. Northwest of the old Phoenix mine the valley deepens gradually into a long basin extending to the Susquehanna River at Scovell Island. Its deepest part lies a short distance north of the present Lackawanna River, but that stream is underlain with 60 to 100 feet of deposits from Duryea to its mouth. In the main buried channel the thickness varies from 100 to 150 feet, there being

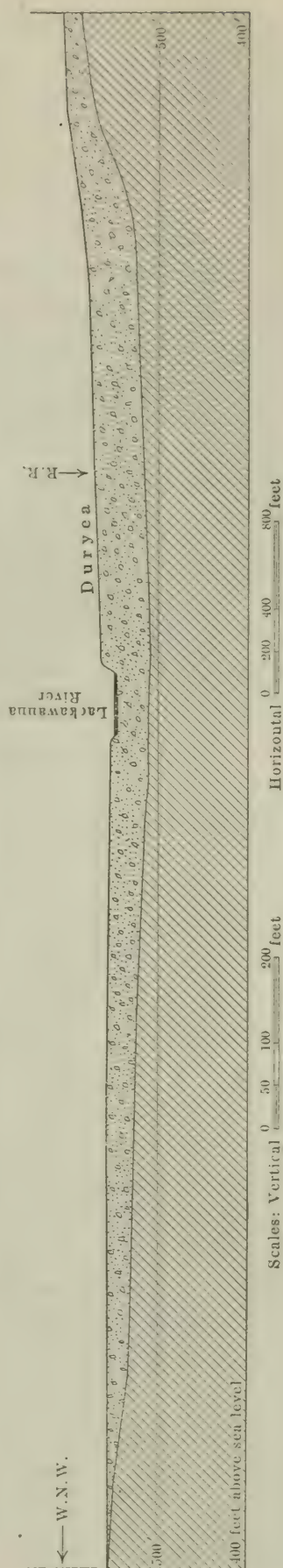


FIGURE 4.—Section across the buried valley of the Lackawanna River at Duryea, Pa.

a nearly regular slope to the bottom in most parts of its course. The materials vary considerably from place to place, but sand and gravel predominate, with streaks of fine, soft sand reported as quicksand in the records. A hole a few rods north of the Seneca shaft penetrated sandy clay 12 feet, gravel 10 feet, and sand 59 feet, on sandstone. Another hole 1,200 feet north by west of Pittston Junction penetrated clay 20 feet, sand 80 feet, gravel and bowlders 45 feet, and sand and coal wash 6 feet, on sandstone. On the north slope of the buried channel a half mile northwest of the Phoenix colliery a bore hole penetrated clay 4 feet, gravel 19 feet, sand 23 feet, and quicksand $27\frac{1}{2}$ feet, on soft rock.

On the north slope of the valley of the Lackawanna River from near Coxton to and into Lackawanna County there is a thick accumulation of till along the lower slope of the mountain. In places near the Babylon and William A collieries this till deposit attains a thickness of considerably more than 50 feet, and it is probably 100 feet thick at some points. Much of the material is very sandy till, which would afford sand to flush present and future mine workings in that district. Water for sluicing and flushing would have to be pumped from the river, 60 to 150 feet below.

TERRACES FROM MOOSIC TO BARBERTOWN.

At Moosic under the Lackawanna River there is a long basin or depression containing more than 100 feet of sand and gravel, and just east of the village there is a high terrace of the same materials, with its top nearly 100 feet above the river. A great volume of sand was deposited at this place, but much of it has been removed by subsequent erosion. The deep basin is not long, for rock ledges rise to the east and south, and ledges cross the river at the mouth of Spring Brook. A deep channel probably extends west under the western part of Moosic and under the northern end of Duryea, but there are no borings for verification. The strongly marked sand-and-gravel terrace of the narrow ridge just east of Moosic extends south to the Spring Brook colliery and ends in the north in a high bluff, in which sand has been extensively excavated for shipment. This high terrace continues again on the northwest side of the river and its level surface extends to Barbertown and thence to the valley of Ascension Brook. Doubtless it marks the old course of that brook. The tonnage of sand and gravel in this terrace is great, but as there is little information as to the position of the underlying rock the quantity can not be closely estimated. There are buildings on part of the area, but there are many sections in which the sand could be utilized for filling the extensive workings of the collieries in the neighborhood.

VALLEY OF ASCENSION BROOK.

There is a large quantity of sand and gravel along the valley of Ascension Brook from its mouth to Pyne. The deposit also extends eastward over the low dividing ridge to Taylor, and it extends northwest some distance up the mountain slope. Some of it is in the form of an irregular high terrace and other parts consist of the usual sheet of till mantling the irregular surface. Its thickness is variable, but in many places it approaches 50 feet and possibly at some points it may be much greater. The region is extensively undermined by the workings of three or four collieries, for the filling of which the sand of this great deposit could be utilized. There is a small flow of water in Ascension Brook, and from the mines there is a fairly large quantity pumped, which could be used for sluicing and flushing sand in the area. Some portions of the till contain many boulders, but so far as observed sand constitutes almost 60 per cent of the deposit, and at some places the proportion is much greater. In the area also sand could be loaded on cars and taken to mines farther north and east when the conditions are such as to warrant the expense of such haulage.

TILL OF THE TAYLOR-HOLDEN AREA.

About the Taylor and Holden collieries there are some thick irregular deposits of glacial till that could furnish a large quantity of sand for mine filling. Portions of the material are rearranged and constitute irregular terraces, and other portions are in morainal hills of which there are some notable examples just north of the Holden colliery. There are buildings on part of the region but in many places sand could be excavated. Along the railroad the till has been removed to some extent for ballast and other uses.

SCRANTON REGION.

In the city limits of Scranton there are wide areas of glacial till and of terrace deposits, both consisting of gravel and sand. On most of these areas, however, there are buildings or lots held for building, so that the quantity of local sand available for mine filling is not large. One of the largest deposits of till lies along the foot of the mountain slope on the north side of Keyser Avenue. It varies in width and thickness but the volume of material is very great. No records of bore holes are available but in the slopes northwest of the Brisbin mine the till is at least 50 feet thick. The material is sand and gravel with many boulders of moderate size. Sand and gravel underlie the valley south of Keyser Avenue and in places extend up the slope south. It is possible that in parts of this valley the sand is sufficiently thick to be handled by dredges

and pumped into the workings of collieries in the neighborhood. Sand from the slopes north might be worked down by hydraulicking. The supply is very great. In the slopes and terraces between the Cayuga colliery and Leggett Creek there are gravel-and-sand deposits extending south over the table land constituting the upper part of Providence. These, however, are so largely built upon as not to be available for mine filling, except that by regrading an area of hilly till lying south of the New York, Ontario & Western Railroad at Pawnee, Henry, and West Market Streets and Keyser Avenue, a large quantity of sand could be obtained. One high hill lies just east of the junction of Keyser Avenue and West Market Street, and there are others extending west to the Cayuga culm dump. In places this dump rises 60 to 70 feet above adjoining street grades, and would furnish near a half million tons of sand. East of Leggett Creek there is a high mound of glacial till extending to the northeast boundary of the city which might yield a large quantity of sand for filling the workings of near-by mines. Water under pressure could be brought from the creek, but unfortunately the low-stage supply is not great. Also there are buildings or building lots on part of the area.

The low flat along the Lackawanna River and the first terrace above widen out in places near Scranton and would furnish some sand, especially if regrading were done. Sand is now being dug extensively above Washington Avenue just west of Roaring Brook, but the tonnage available here is not great. A small mass of till rises above the grade on the square bounded by Palm and Pear Streets and Pittston and Cedar Avenues.

DICKSON TO PECKVILLE.

For several miles above Dickson the surface of the valley of the Lackawanna River is composed almost entirely of till and of alluvial deposits, mostly sand and gravel. The thickness is not great at most points and there are many buildings on the area, but a great quantity of material is available for dredging or hydraulicking. There is about 50 per cent of gravel and bowlders which could be either discarded, or crushed and utilized. One of the largest areas of sandy material is in the open land just west of Blakely. There are in this tract several sand pits from which sand is taken for building or for making concrete. The pits show that the percentage of sand is high, and the thickness of the bank is at least 30 or 40 feet. A bore hole in the middle of this tract, on the line of First Street extended, penetrates 59 feet of sand and gravel before reaching bed-rock, so that the latter is at a level considerably below that of the river bed a short distance southeast. Another hole on the line

of Fourth Street extended entered the bedrock at a depth of 18½ feet, showing that the thickness of the deposit diminishes rapidly to the northwest. There are in this tract about 5,000,000 tons of sand available for filling the extensive mine workings under this part of the valley.

In the Lackawanna shaft there is 53 feet of cribbing to bedrock. This thickness is probably representative of the valley filling at this place; the amount may be greater nearer the center of the valley approaching Peckville and in the western part of Olyphant. In Peckville there are low ridges and hills of sand and gravel, but there are buildings over most of the area, so that the only sand available would result from regrading or from excavation of the scattered vacant places.

WILDCAT CREEK REGION.

The ridges between Millers Creek and Wildcat Creek and the slopes eastward consist of an irregular covering of glacial till. It is mostly sand with 30 to 40 per cent of gravel and in places a considerable proportion of large boulders. The thickness is variable, but some of the ridges appear to be made up entirely of till and, if they are so constituted, the thickness over a large area is more than 50 feet. The quantity of sand suitable for mine filling is very great and there is some water available for sluicing and flushing.

JESSUP AREA.

The upper portion of the village of Jessup is built on till which in places may attain a thickness of 30 to 50 feet. Parts of it are very coarse, but in a portion of the area there is some sand which could be excavated.

ARCHBALD.

Archbald is built on an irregular till plain which is underlain with much sand and gravel, but probably little of the material could be utilized for mine filling. The best source of supply at this place would be dredgings from the river which would immediately furnish a moderate supply and create a basin in which there could accumulate sand and other material carried by the river in times of freshet.^a

JERMYN AREA.

About Jermyrn the valley of the Lackawanna River widens for the distance of a mile or more. In this area there are terraces of rearranged glacial sand and gravel and more or less unmodified till consisting largely of sand, gravel, and boulders. There are buildings over much of it, but there are a few places where considerable sand

^a Griffith, William, and Conner, E. T., Mining conditions under the city of Scranton, Pa.: Bull. 25, Bureau of Mines, 1912, p. 62.

might be excavated for filling the mines that have been worked under this district. Doubtless much material could be obtained from the river by dredging out the sand and creating basins in which some of the sediment of the river would be intercepted.

COMPARATIVE SUITABILITY OF MATERIALS FOR MINE FILLING.

It is generally conceded that sand is the strongest roof-supporting material that can be flushed into mines. A series of tests made for William Griffith and E. T. Conner in the physical laboratory of Lehigh University has given some valuable figures as to comparative strengths of various materials that are available for mine filling. The figures following are taken or compiled from the report ^a of these investigators. The tests were made with Delaware River sand confined in a cylinder 10 $\frac{7}{8}$ inches high and 6 $\frac{7}{8}$ inches in diameter. Pressure was applied with a close-fitting piston. It should be borne in mind that the figures given are from a single series of tests. Further tests are contemplated by the Bureau of Mines.

Compression of Delaware River sand confined in a cylinder.

Pressures, pounds.....	5,000	20,000	40,000	100,000	300,000
	COMPRESSIONS.				
	Inches.	Inches.	Inches.	Inches.	Inches.
Dry sand, 10 $\frac{7}{8}$ inches thick.....	0.65	1.22	1.66	2.39	3.35
Flushed sand, 9 $\frac{3}{4}$ inches thick.....	.12	.31	.56	1	1.93

Nine inches of flushed culm (damp) showed a compression of 3 inches, or nearly one-third, under a total load of 150 tons; and broken sandstone of sizes 1 $\frac{3}{4}$ inches down, with its 40 per cent voids filled with sand, showed 2.4 inches compression under the same load. Expressed in percentages of compression, the following results were obtained:

Compression percentages of Delaware River sand confined in a cylinder.

Compression percentage.....	3	5	10	20
	LOADS.			
	Tons.	Tons.	Tons.	Tons.
Dry sand, 10 $\frac{7}{8}$ inches thick.....	3	14 $\frac{1}{2}$	33	129
Flushed sand, 9 $\frac{3}{4}$ inches thick ^b	39.3	67	173.8	555.4

^a Griffith, William, and Conner, E. T., Mining conditions under the city of Scranton, Pa.: Bull. 25, Bureau of Mines. 1912. 89 pp., 2 pls.

^b Wet and partly drained.

These pressures calculated into the thickness of an equivalent weight of sandstone and shale such as overlie the coal beds give the following results:

Compressibility of sand and culm under rock pressure.

Compression percentage.....	1	3	5	10	20
	REQUIRED THICKNESS OF ROCK.				
	Feet.	Feet.	Feet.	Feet.	Feet.
Mine chamber filled with dry sand.....	12	40	70	442	1,715
Mine chamber flushed with sand.....	111	522	891	2,310	^a 8,000
Mine chamber flushed with culm.....	32	118	191	472	1,822

^a Calculated from figures for 20½ per cent compression.

The probable rock pressure in coal-mine workings 500 feet deep is about 580 pounds to the square inch, and in workings 1,000 feet deep about 1,160 pounds. These figures correspond closely to the 20,000 and 40,000 pound pressures in the cylinder tests mentioned above. These tests indicated a compression of approximately 11 per cent for a 20,000-pound pressure and of 15 per cent for a 40,000-pound pressure with loose sand, and of 3 per cent and 5½ per cent, respectively, with flushed sand. The latter figures would represent a maximum subsidence of less than 4 inches for a 10-foot coal bed completely worked out and replaced with flushed sand at a depth of 500 feet. In practice, however, the amount would be less.

Several years ago a committee of the Scranton Engineers' Club had a series of coal samples tested to find the probable strength of pillars. The results varied greatly with different coals, but in general indicated that a pressure of 200 to 250 tons per square foot will start the crushing of pillars, and that about twice as much pressure will crush them completely.^a

It has been suggested that much of the material along the Susquehanna River and under its flats is quicksand, and is therefore not suitable for being run into a mine. The word "quicksand" is a relative term and is loosely applied to a variety of materials from coarse, sharp sand to pure clay completely mixed with water. Usually it signifies fine sand mixed with water, a material which would serve admirably for filling mine chambers as the quicksand would travel better than coarse sand and would set much more compactly when the water was drained off through the battery partitions. The conclusion is warranted, however, that if large bodies of sand are placed in chambers their continuity should be interrupted by stout pillars or barriers at suitable intervals. Possibly, also, some cementing material may be found that could be introduced with the sand to stop or decrease its mobility.

^a See Bull. 25, Bureau of Mines, p. 78.

QUANTITY OF FILLING REQUIRED AND AVAILABLE.

In the report of the Pennsylvania Coal Waste Commission, published in 1893, there are given estimates of the quantity of coal in the various fields as computed by A. D. W. Smith. For the northern anthracite field, with a total area of 110,876 acres, or 176 square miles, the figure is 5,666,219,784 tons. This is equivalent to an average thickness of coal over that area of slightly more than 27 feet. A material proportion of this coal has already been removed.

In many areas of large extent the total thickness of the several coal beds is greater than 70 feet (pure coal), this being the case under much of the Wyoming Valley and part of the Lackawanna and Newport Valleys. Figure 5 shows a typical general section near the city of Wilkes-Barre compiled from various sources.

At Scranton there is somewhat less coal, but, according to Griffith and Conner,^a its average thickness is nearly 58 feet, comprising the following beds:

Two-foot, 4.4 feet; Four-foot, 3.6 feet; Diamond, 9.4 feet; Rock, 5.2 feet; Big bed, 12.2 feet; New County, 6 feet; Clark, 6.7 feet; Dunmore No. 1, 3 feet; Dunmore No. 2, 4 feet, and Dunmore No. 3, 3.3 feet.

Griffith and Conner find that 221,000,000 tons of coal and refuse, or about half of the coal under the city, had been removed at the beginning of

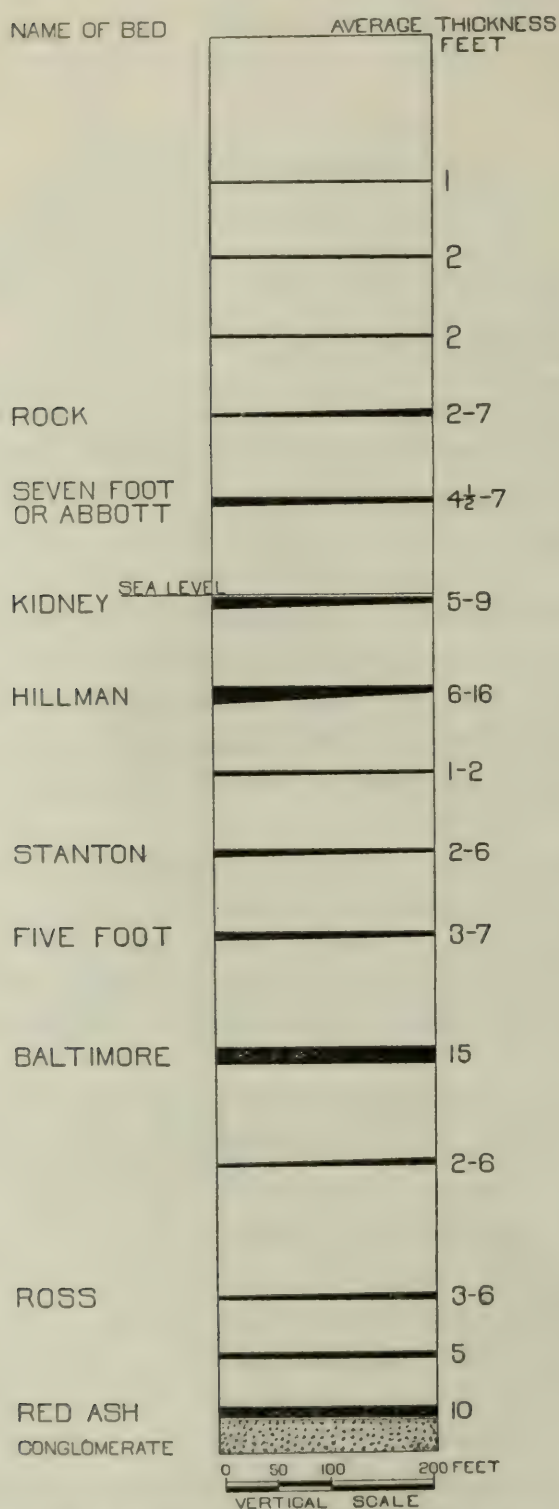


FIGURE 5.—Generalized section of the coal measures near Wilkes-Barre, Pa.

1910. This tonnage represents a space of 198,000,000 cubic yards,

^a Griffith, William, and Conner, E. T., Mining conditions under the city of Scranton, Pa.: Bull. 25, Bureau of Mines, 1912, pp. 44-51.

probably diminished somewhat by caves and squeezes. A large quantity of the coal remaining at Scranton is in the deep-lying Dunmore beds.

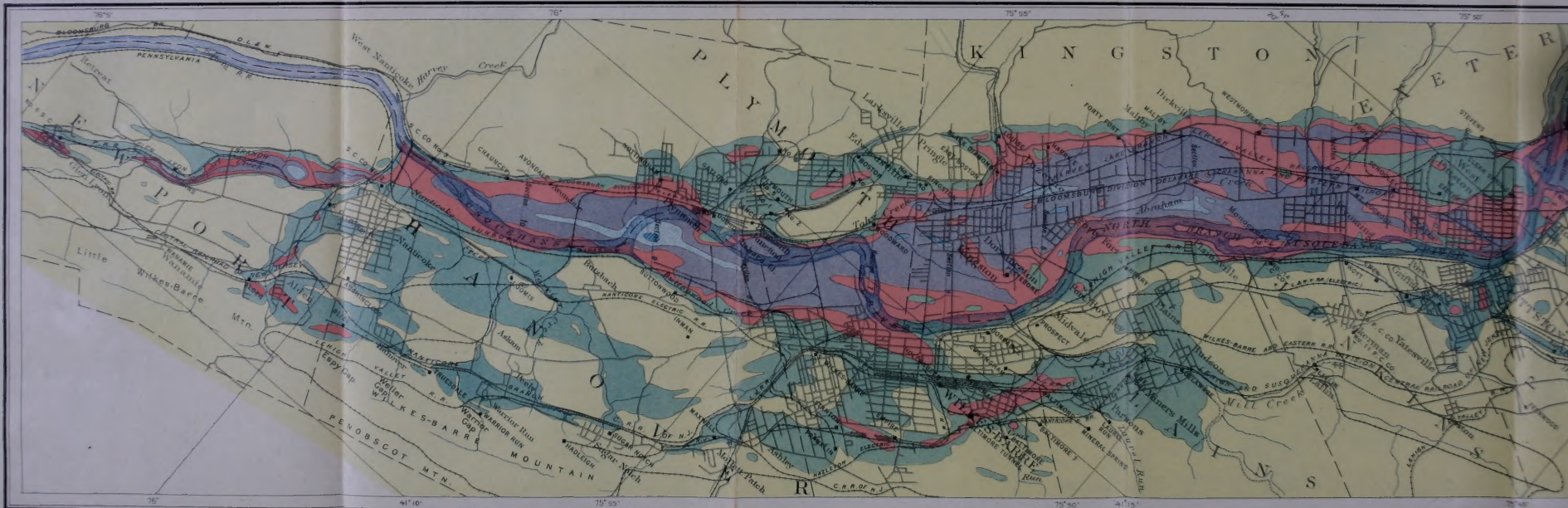
It was the ordinary practice to leave about one-third of the coal for pillars, and it is estimated that one-quarter of the excavated material is waste which can be replaced in the mine.

These data show that the quantity of sand required to fill coal workings made in the past and to be made in the future is very great. The total quantity necessary to replace all the coal that can in the future be shipped under present conditions is about 10,000,000,000 tons, or sufficient to cover to a depth of nearly 25 feet the coal-basin area of 176 square miles. This is more than twice as much material as is contained in the buried valley of the Susquehanna River, but it is about the same quantity as the contents of that valley, together with all the till and terrace deposits in the northern coal basin.





MAP SHOWING BURIED CHANNEL OF SUSQUEHANNA RIVER,
 FILLED WITH SAND AND GRAVEL IN PART SUITABLE FOR FILLING MINE WORKINGS.
 LUZERNE COUNTY, PENNSYLVANIA

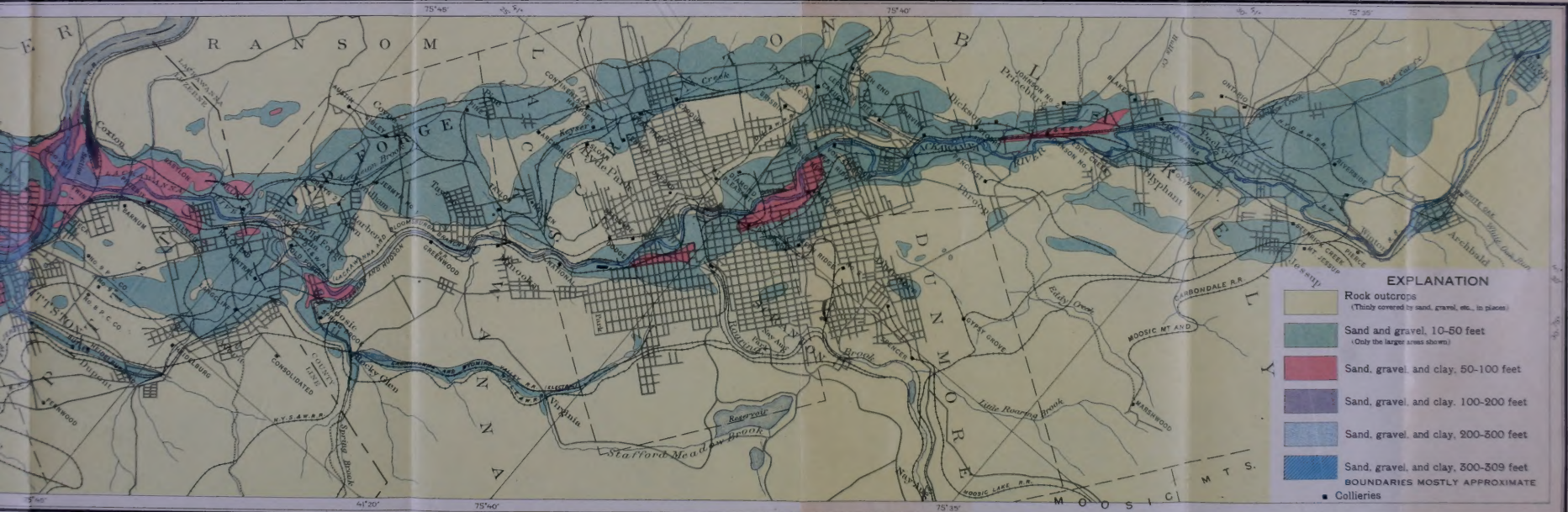


BASE MAP BY U. S. GEOLOGICAL SURVEY 1889-1891 WITH ADDITIONS

MAP SHOWING DISTRIBUTION OF SAND AND GRAVEL IN PART

BY N. H. DARTON

Scale, miles



IN PART OF THE NORTHERN ANTHRACITE COAL BASIN, PA.

N. H. DARTON

Scale 1:250,000

1 Mile

